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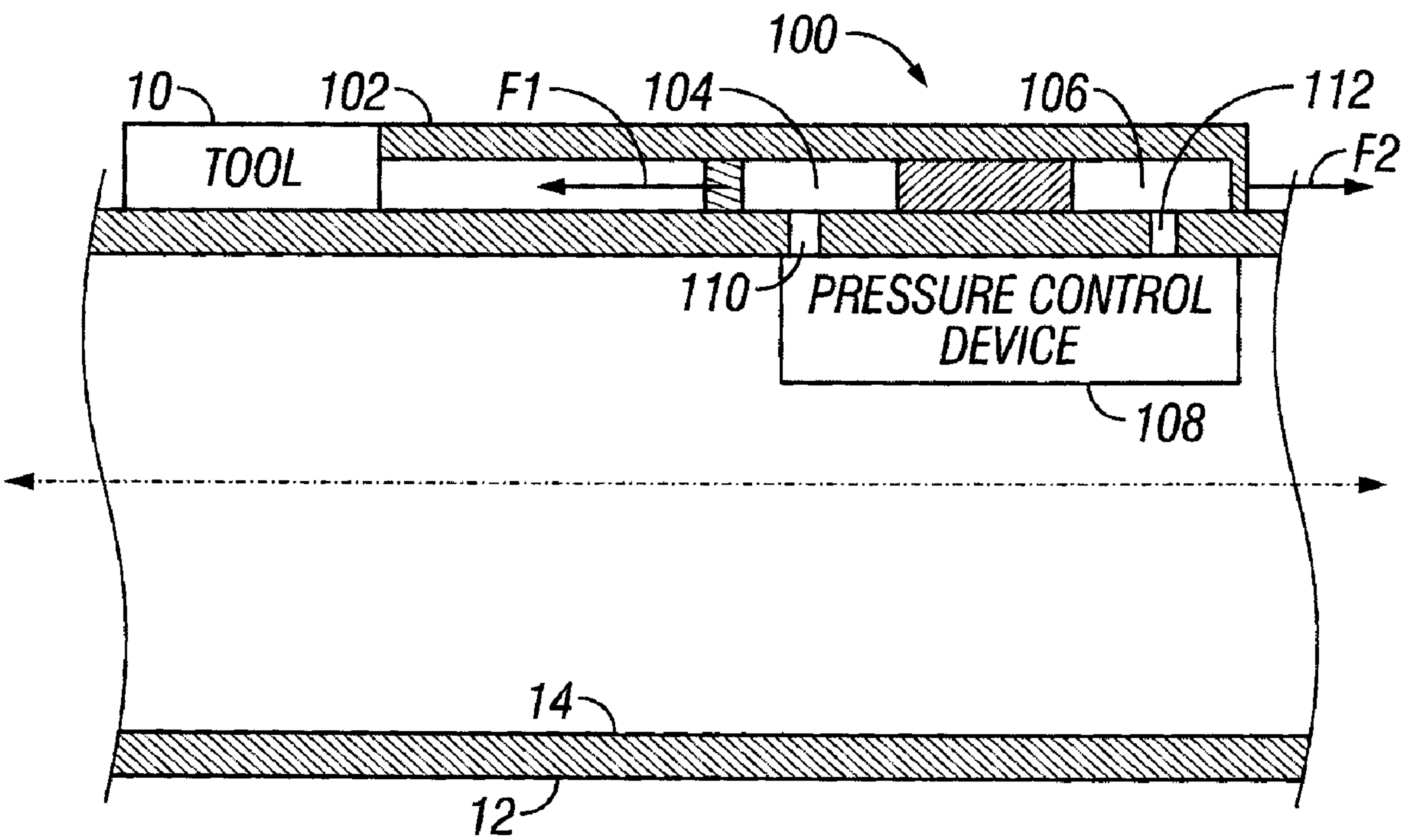


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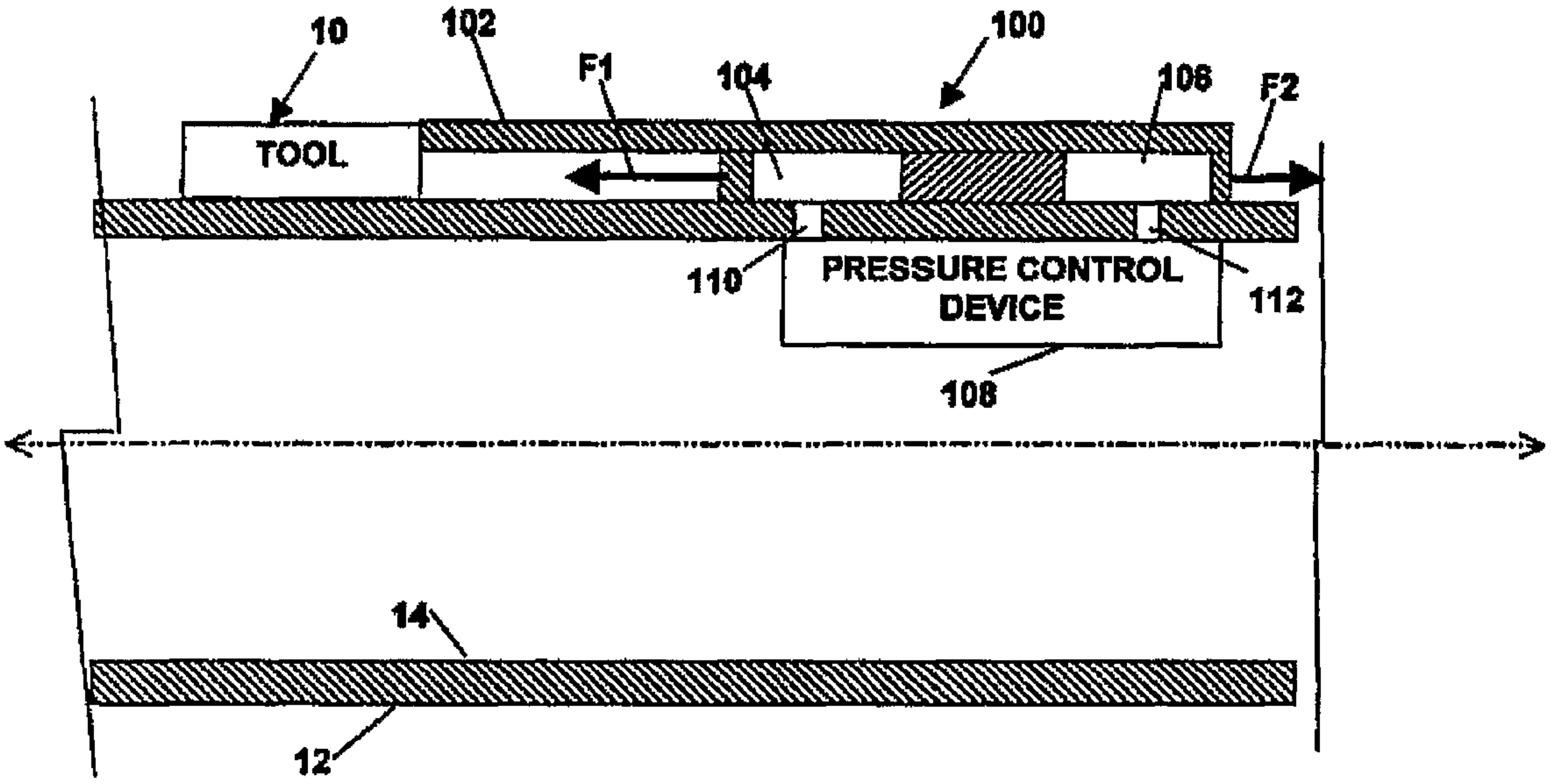


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WO 2007/008455 A1

# SYSTEM AND METHOD FOR ACTUATING WELLBORE TOOLS

## BACKGROUND OF THE INVENTION

### Field of the Invention

[0001] The present invention relates to systems for actuating one or more tools adapted for use in a wellbore.

### Description of the Related Art

[0002] Hydrocarbons such as oil and gas are recovered from a subterranean formation using a wellbore drilled into the formation. A number of tools are used throughout the process of drilling and completing the wellbore and also during the production life of the well. Many of these tools are energized using pressurized fluid that is self-contained in the tool, pumped downhole from the surface, or fluid that is produced from the well itself. These tools, which are sometimes referred to as hydraulically actuated tools, can be put to a number of uses.

[0003] One use for hydraulically actuated tools is to set a liner hanger. During drilling, the wellbore is lined with a string of casing that is cemented in place to provide hydraulic isolation and wellbore integrity. Commonly, multiple strings of casing are set in a well in a successive fashion. For example, a first string of casing is set in the wellbore after the well is drilled to a first depth and a second string of casing is run into the wellbore after the well is drilled to a second depth. The second string is set such that the upper portion of the second string of casing overlaps with the lower portion of the first string of casing. Any string of casing that does not extend back to the surface is generally referred to as a liner. The second string is then cemented into the wellbore as well. This process may be repeated as needed.

[0004] The liner hanger is used to hang or anchor a liner off of a string of other casing string. Several types of liner hangers are known in the art, which includes hydraulic liner hangers. In conventional hydraulic liner hangers, fluid is supplied under pressure into an annular space between a mandrel and a surrounding cylinder. The hydrostatic pressure of the fluid between the cylinder and the mandrel creates a force on the inner surface area of the cylinder that causes the cylinder to slide longitudinally.

[0005] Conventionally, the hydraulic liner hanger is set by applying a predetermined level of hydrostatic pressure to the liner hanger. That is, the liner hanger is run into the wellbore while in contact with a fluid having a first hydrostatic pressure and then actuated by increasing the pressure in the fluid. In an conventional arrangement, a ball is dropped into the wellbore and landed on a seat that is positioned generally downhole of the liner hanger. Fluid is then injected into the wellbore under pressure in order to actuate the hydraulic liner hanger.

[0006] Conventional hydraulic liner hangers can prematurely set if there is a pressure spike of sufficient magnitude in the drill string or if the pressure of the fluid external to the liner hanger unexpected drops. Conventional measures to prevent unintended setting of the liner hanger include the use of shear pins to mechanically restrain the cylinder while the liner assembly is run into the hole and closures or flow restriction devices that prevent fluid from entering the hydraulic liner hanger until the liner hanger is ready to be set.

[0007] These conventional measures have various drawbacks that include, but are not limited to, expense and tool complexity. These conventional measures may also impose undesirable constraints in deployment of the liner hanger such as permissible bounds for drilling fluid circulation pressures and flow rates. Moreover, the drawbacks of conventional hydraulic liner hanger are merely illustrative of the general drawbacks of wellbore tools in general that operate using hydrostatic pressure while in the wellbore.

[0008] The present invention addresses these and other drawbacks of the prior art.

## SUMMARY OF THE INVENTION

[0009] In aspects, the present invention provides systems, devices, and methods for actuating a wellbore tool. An exemplary actuator made in accordance with the present invention is operatively coupled to the wellbore tool and conveyed into a wellbore via a work string. When the fluid in the work string reaches a predetermined applied pressure, the actuator undertakes a specified action such as longitudinal motion, rotation, expansion, etc that actuates or operates the wellbore tool. Premature actuation of the wellbore tool is prevented by applying to the actuator a resistive force that, alone or in cooperation with another mechanism, arrests or restrains movement of the actuator. This resistive force is generated by applied pressure of the fluid in the work string.

[0010] In one arrangement adapted for use on a drill string, the actuator includes an actuating member having a first and a second pressure chamber. The actuator also includes a pressure control device that can control the pressure in the two chambers. The two pressure chambers are independently hydraulically coupled to the fluid in the drill string and are arranged such that the pressures in the chambers generate opposing forces, a motive force and a resistive force, on the actuating member. In one embodiment, the actuating member includes a cylinder slidably disposed on a mandrel. The pressure chambers, which are formed between the cylinder and mandrel, communicate with the drill string fluid via ports formed in the mandrel. When needed, the pressure control device forms a hydraulic seal between the two chambers by using, for example, a sealing member and occlusion member. This hydraulic seal hydraulically couples the first pressure chamber to the fluid uphole of the hydraulic seal. The fluid downhole of the hydraulic seal and the second pressure chamber are largely isolated from pressure increases in the uphole fluid due to the hydraulic seal.

[0011] To activate the actuator and thereby actuate the wellbore tool, the pressure in the first chamber is increased relative to the pressure in second chamber. For example, after the hydraulic seal is formed by the pressure control device, a surface pump can be energized to increase the applied pressure in the fluid uphole of the hydraulic seal. When so energized by the pressurized fluid, the magnitude of the motive force generated by the first pressure chamber increases. When an adequate pressure differential exists, the motive force overcomes the resistive force and the actuating member is thereby displaced. The displacement of the actuating member in turn actuates the wellbore tool.

**[0012]** The actuator can be configured to operate liner hangers as well as other tools used in the wellbore. Moreover, in addition to drilling fluid, the pressurized fluid can be water, synthetic material, hydraulic oil, or formation fluids.

**[0012a]** Accordingly, in one aspect of the present invention there is provided a method for actuating a wellbore tool, comprising:

(a) operatively connecting an actuator to the wellbore tool;

(b) conveying the wellbore tool and the actuator into a wellbore;

(c) preventing activation of the actuator by using a resistive force that is generated at least partially by an applied pressure of a fluid in the wellbore; and

(d) activating the actuator by overcoming the resistive force.

**[0012b]** According to another aspect of the present invention there is provided an apparatus for actuating a tool adapted for use in a wellbore, comprising:

(a) an actuator operatively coupled to the wellbore tool;

(b) a first pressure chamber adapted to generate a motive force that displaces the actuator;

(c) a second pressure chamber adapted to generate a resistive force that resists motion of the actuator; and

(d) a pressure control device that selectively applies pressure to the first and second pressure chambers.

**[0012c]** According to yet another aspect of the present invention there is provided a system for operating a tool for use in a wellbore, comprising:

(a) a rig at a surface location;

(b) a work string adapted to convey the tool into the wellbore from the rig;

(c) an actuator coupled to the tool, the actuator including a first and second pressure chamber in communication with a fluid in the work string, the first and second chambers adapted to generate forces in substantially opposing directions; and

(d) a pressure control device adapted to selectively substantially hydraulically isolate the first and second pressure chambers from each other.

**[0013]** It should be understood that examples of the more important features of the invention have been summarized rather broadly in order that detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]** For detailed understanding of the present invention, references should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

**[0015]** **Figure 1** schematically illustrates one embodiment of an actuating tool made in accordance with the present invention;

**[0016]** **Figures 2A** and **2B** schematically illustrate sectional views of an embodiment of an actuating tool made in accordance with the present invention that is adapted for use in connection with a liner hanger;

**[0017]** **Figures 3A** and **3B** illustrate sectional views of embodiment of pressure chambers in accordance with the present invention;

[0018] **Figure 4** schematically illustrates one embodiment of a pressure control device made in accordance with the present invention that uses a closure;

[0019] **Figure 5** schematically illustrates one embodiment of a pressure control device made in accordance with the present invention that uses a flow restriction device; and

[0020] **Figure 6** schematically illustrates a sectional elevation view of a liner drilling system utilizing an actuating tool made in accordance with the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] The present invention relates to devices and methods for actuating wellbore tools. The present invention is susceptible to embodiments of different forms. There are shown in the drawings, and herein will be described in detail, specific embodiments of the present invention with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein.

[0022] Referring initially to **Fig. 1**, there is schematically illustrated one embodiment of a tool actuator **100** made in accordance with the present invention for operating a tool **10** conveyed via a work string **12** into a wellbore. The tool actuator **100**, as will be described in further detail below, operates in response to the applied pressure of the fluid. Applied pressure is generally defined as the total pressure applied by the fluid. The total pressure can be the hydrostatic pressure or can be the sum of several components such as hydrostatic pressure, dynamic pressure losses, and a pressure differentials caused by a device such as a surface mud pump or downhole pump. The actuator **100** includes an actuating member **102** connected directly or indirectly to the tool **10**, a first pressure chamber **104**, a second pressure chamber **106**, and a pressure control device **108**. The pressure control device **108** controls the pressure in each chamber **104** and **106**. The pressures in chamber **104** and **106** each generate a force on the actuating member **102** that substantially oppose one another. When the two chambers **104** and **106** have generally equal pressures, the opposing forces balance and the actuating member **102** remains stationary. When desired, the pressure control device **108** can vary the pressure in one of the two chambers **104** and **106** to cause a net force that causes the actuating member **102** react in a preset manner such as sliding, rotating, extending, retracting, etc. The reaction of the actuating member **102** thereby actuates the tool **10**.

**[0023]** In one arrangement, the actuator **100** is energized using pressurized fluid in a bore **14** of the work string **12**. The first and second pressure chambers **104** and **106** hydraulically communicate with the bore **14** via ports **110** and **112**, respectively. The first pressure chamber **104** generates a motive force **F1** adapted to displace the actuating member **102** whereas the second pressure chamber **106** generates a resistive force **F2** that temporarily or selectively offsets the force **F1** created by the first pressure chamber **104**. In such an arrangement, as long as chambers **104** and **106** communicate with pressurized fluid having the same hydraulic pressure, then the pressure values in the chambers **104** and **106** and corresponding generated forces will be substantially equal and the actuating member **102** will remain stationary, *i.e.*, motion will be substantially arrested.

**[0024]** It should be appreciated that the actuating member **102** will remain stationary even if the applied pressure of the fluid in the bore **14** significantly and unexpectedly increases while the tool **100** is being run into the wellbore or sometime thereafter. This is so because the increased applied pressure will be applied to both chambers **104** and **106**. Thus, while the magnitude of the motive force **F2** may increase due to a pressure spike, the magnitude of the resistive force **F2** will also increase since the applied pressure of the fluid that energizes the first pressure chamber **104** also energizes the second pressure chamber **106**. Thus, the resisting force **F2** will act to cancel the motive force **F1** and thereby minimize the risk that the actuating member **102** will move. In like manner, if the pressure of the fluid external to the tool **100** unexpectedly drops, this pressure drop will not cause movement of the actuating member **102**

because the second pressure chamber **104**, and the resistive force it generates, arrests movement of the actuating member **102** using the applied pressure of the fluid internal to the tool **100**.

[0025] When desired, the pressure control device **108** can cause a pressure imbalance or differential by allowing fluids having different applied pressures to communicate with each chamber **104** and **106**. Upon the pressure differential reaching a preset or predetermined value, the net force generated by the first pressure chamber **104** overcomes the opposing force of the second pressure chamber **106** and displaces the actuating member **102**, which then actuates the tool **10**.

[0026] It should be understood that the pressure chamber **106** need not provide the exclusive resistive force or mechanism for offsetting the motive force **F1**. For instance, a biasing member or spring can be utilized to provide a preset amount of resistance against movement of the actuating member **102**. Moreover, a shear pin or other frangible member can be used to increase the resistance the motive force **F1** must overcome before displacing the actuating member **102**. It should also be understood that the resisting force **F2** does not necessarily cause motion of the actuating member **102**. That is, the force **F2** can act to maintain the actuating member **102** at a limit or end point of a stroke of the actuating member **102**.

[0027] As will become apparent, the teachings of the present invention can be utilized for a variety of well tools and in all phases of well construction and production. Accordingly, the embodiments discussed below are merely illustrative of the applications of the present invention.

[0028] Referring now to **Figs. 2A** and **2B**, there is shown an embodiment of an actuator **120** adapted to actuate a liner hanger **50**. The liner hanger is conventionally arranged and includes devices such as slips **52**, a slip retainer **54**, and a shear pin **56**. A work string or other suitable conveyance device (not shown) can be used to convey this and other equipment into a wellbore. The actuator **120** is energized by the applied pressure of fluid in an inner bore **126** of the actuator **120**. The actuator **120** is coupled to the slip retainer **54** and is configured to move the slips **52** longitudinally when the applied pressure in the bore **126** reaches a predetermined value. During this longitudinal movement, the slips **52** extend radially outward and engage a casing wall.

**[0029]** In one embodiment, the actuator **120** includes an inner mandrel **128** concentrically disposed within a surrounding cylinder **130**. The cylinder **130** is adapted to slide longitudinally along the mandrel **128**. For ease of assembly, the cylinder **130** includes an upper cylinder section **132**, a spacer **134**, and a lower cylinder section **136**. The spacer **134** connects together the upper and lower cylinder sections **132** and **136** such that the cylinder **130** operates as one integral member. Other embodiments of the cylinder **130**, of course, could have greater or fewer constituent parts. The actuator **120** includes a first pressure cavity or chamber **140** formed in the upper cylinder section **132** and a second pressure cavity or chamber **142** formed in the second cylinder section **136**. Ports **144** and **146** formed in the inner mandrel **128** hydraulically couple the chambers **140** and **142** to the inner bore **126**. As will be described in further detail below, a pressure imbalance or differential between the two chambers **140** and **142** create a net force that causes longitudinal movement of the cylinder **130**.

**[0030]** Referring now to **Fig. 3A**, there is shown an exemplary arrangement of the chamber **140** for generating the motive force **F1** for displacing the cylinder **130**. During use, fluid in the bore **126** flows through the port **144** and fills the chamber **140**. The hydraulic pressure of the fluid in the chamber **140** applies a force to the surfaces defining the chamber **140**. Upon a predetermined pressure differential being caused between the chamber **140** and the chamber **142**, the cylinder **130** moves longitudinally along the direction specified with arrow **B**. To prevent or minimize the fluid from leaking out of the chamber **140**, the chamber can include seals **152A** and **152B**. In one embodiment, the seal **152A** is a movable sealing element that moves generally with the cylinder **130** and the seal **152B** is a stationary sealing element that is fixed to the inner mandrel **134** with suitable devices such as snap rings **153**. It should be understood, however, that other embodiments having different sealing elements may be utilized and that in still other embodiments the sealing elements can be omitted entirely.

[0031] Referring now to **Fig. 3B**, there is shown an exemplary arrangement of the chamber **142** for providing a resisting force **F2** that at least partially offsets the motive force **F1** to at least temporarily arrest of restrain motion of the cylinder **130.** During use, fluid in the bore **126** flows through the port **146** and fills the chamber **142**. The hydraulic pressure of the fluid applies a force to the surfaces defining the chamber **142**. This force urges the cylinder **130** in the direction specified with arrow **C**, which is substantially opposite of arrow **B**. Similar to the chamber **140**, the chamber **142** can include seals **162A** and **162B**. In one embodiment, the seal **162A** is a movable sealing element that moves generally with the cylinder **130** and the seal **162B** is a stationary sealing element that is fixed to the inner mandrel **128** with suitable devices such as snap rings **163**.

[0032] It will be understood that the magnitude of the pressure differential that initiates motion of the cylinder **130** will depend on factors such as frictional forces, the applied pressure external to the tool actuator **100**, the shear strength of any shear pins that may be used to secure the slip assembly, etc.

[0033] Referring now to **Figs. 1,2A-2B**, a pressure control device **170** selectively controls the pressures in the chambers **140** and **142**. The pressure control device **170** is positioned between the ports **144** and **146** to thereby selectively hydraulically isolate the chambers to which the ports **144** and **146** respectively connect. The pressure control device **170** can maintain substantially equal pressures in the chambers **140** and **142** and also vary the pressure in either of the two chambers **140** and **142** to cause a pressure imbalance therebetween. For example, the pressure control device **170** can for one period of time maintain substantially equal pressures in the chambers **140** and **142** and in a successive period of time selectively increase the pressure in the chamber **140** or decrease the pressure in chamber **142**. Numerous embodiments of the pressure control device **170** can be utilized, a few of which are discussed below.

[0034] Referring still to **Figs. 1,2A-2B**, in one embodiment, the pressure control device **170** includes a sealing member **172** and an occlusion member **174** that cooperate to at least temporarily occlude the bore **126** of actuator **120.** During run in of the wellbore tool **100** and before actuation is required, the sealing member **172** permits flow through the bore **126**. To initiation activation of the actuator **120**, the occlusion member **174** is introduced at the surface into the tubular connecting the actuator **120** to the surface (*e.g.*, drill string, coiled tubing, production string, etc.). The occlusion member **174** travels down the tubular and mates with the sealing member **172**, which has an opening or passage equal to or less than the size of the occlusion member **174**. The occlusion member **174** can include a ball, a plug or other object configured to create a barrier across the sealing member **172**.

**[0035]** When the occlusion member **174** and the sealing member **172** mate, a hydraulic seal is formed between the port **144** and the port **146**. This seal, which does not need to be a "zero leakage" seal, enables a substantial pressure differential thereacross. Thus, the pressure chambers **140** and **142** are in communication with two hydraulically independent bodies of fluid. The two bodies of fluid need not be completely isolated from one another, *e.g.*, there can be some fluid or hydraulic communication between the two fluid bodies.

**[0036]** Merely for convenience, the fluid in region **180**, which communicates with the chamber **140,** will be referred to as the uphole fluid and the fluid in region **182**, which communicates with the chamber **142**, will be referred to as the downhole fluid. The pressure of the uphole fluid can be controlled, *e.g.,* increased, using a device such as a mud pump. Increasing the pressure of the uphole fluid will, of course, increase the pressure in the first chamber **140**. Because of the seal provided by the pressure control device **170**, the pressure of the downhole fluid and the fluid in the second chamber **142** remains mostly at hydrostatic pressure and are largely unaffected by the increased pressure in the uphole fluid.

**[0037]** Thus, initially, the motive force **F1** and resistive force **F2** will cancel due to the first and second chambers **140** and **142** receiving fluid having the same applied pressure. However, after occlusion of the bore **126**, the increase of applied pressure in the uphole fluid and in the first chamber **140** will cause a corresponding increase in the magnitude of the force **F1**. Because the pressure in the downhole fluid is mostly static, the resistive force **F2** does not change. At a predetermined pressure differential between the chambers **140** and **142**, the motive force **F1** overcomes the resistive force **F2** and longitudinally displaces the cylinder **130**. The cylinder **130** via its connection to the slip retainer **54** actuates or sets the slips **52**.

**[0038]** It should be appreciated that the temporary occlusion in the well provides a hydraulic path to the chamber inducing the motive force while isolating or uncoupling the chamber inducing the resistive force from that hydraulic path. In addition to a surface pump increasing hydraulic pressure, other devices such as a downhole pump or even pyrotechnics can be used to selectively increase hydraulic pressure in that hydraulic path.

**[0039]** In one arrangement, after the slips **52** are set, pressure of the uphole fluid is further increased until the sealing member **172** deforms and allows the occlusion member **174** to pass therethrough. After the occlusion member **174** unseats and passes through the sealing member **172**, hydraulic communication and fluid flow is reestablished along the bore **126**. In certain embodiments, the sealing member **172** and occlusion member **174** can be configured to permit multiple selectively blockages of the bore **126**.

**[0040]** Other selective bore restriction devices suitable for use in embodiments of the present invention are disclosed in U.S. Pat. 5,146,992 and U.S. Patent No. 6,966,368.

**[0041]** Referring now to **Fig. 4**, there is shown a pressure control device **200** including an operator **202** that selectively displaces a closure member **204**. The closure member **204** is adapted to partially or completely seal the port **146** leading to the second pressure chamber **142** to thereby effectively isolate the second pressure chamber **142**. The pressure control device **200** can be adapted for either "one time" usage or multiple sealing and unsealing of the port **146** and can include a mechanical device, electro-mechanical device, hydraulic motor or other suitable device. For example, the operator can include a biasing member that applies a spring force, a pressure chamber actuated by hydraulic fluid, an electric motor, frangible devices that restrain the closure member **204**, etc.

**[0042]** Referring now to **Fig. 5**, there is shown another embodiment of a pressure control device **210** that includes a flow restriction device **212** such as a valve that selectively controls flow across the port **146**. The flow rate of the flow restriction device **212** can be adjusted using a solenoid or other suitable device. In still other embodiments, the pressure control device can merely include ports of differing cross-section flow areas. Referring now to **Figs. 3A-3B**, for example, the port (or ports) for the chamber **140** can have a larger cross-sectional flow area than the port (or ports) for the chamber **142**. The cross-sectional area differential can be selected such that the increase in hydraulic pressure in the bore is communicated faster to the chamber **140** than to chamber **142** to thereby provide a desired pressure differential between the chambers **140** and **142**.

**[0043]** It should be appreciated that the pressure control device, whatever the particular configuration, can control the degree to which hydraulic pressure in the bore is communicated to the pressure chambers. Moreover, it should be appreciated that fluid communication between the bore and the chambers need not be completely blocked in order to cause a desired pressure differential.

**[0044]** Referring now to **Fig. 6**, there is shown a well construction facility **230** positioned over subterranean formation **232**. While the facility **230** is shown as land-based, it can also be located offshore. The facility **230** can include known equipment and structures such as a derrick **234** at the earth's surface **236**, a casing **238**, and mud pumps **240**. A work string **242** suspended within a well bore **244** is used to convey tooling and equipment into the wellbore **244**. The work string **242** can include jointed tubulars, drill pipe, coiled tubing, production tubing, liners, casing and can include telemetry lines or other signal/power transmission mediums that establish one-way or two-way data communication and power transfer from the surface to a tool connected to an end of the work string **242**. A suitable telemetry system (not shown) can be known types as mud pulse, electrical signals, acoustic, or other suitable systems. The tooling and equipment conveyed into the wellbore can include, but are not limited to, bottomhole assemblies, tractors, thrusters, steering units, drilling motors, downhole pumps, completion equipment, perforating guns, tools for fracturing the formation, tools for washing the wellbore, screens and other production equipment.

[0045] For illustrative purposes, the work string **242** is shown as including a drill string conveying a bottomhole assembly adapted for liner drilling ("liner drilling assembly") **246** into the wellbore **244**. Exemplary liner drilling systems are discussed commonly assigned U.S. Patents 5,845,722 and 6,196,336. The liner drilling assembly **246** includes a liner hanger **248** and an actuator **250**.

[0046] Referring now to **Figs. 2-6**, in an exemplary deployment, the liner drilling assembly **246** drills the wellbore **244** while the mud pump **240** circulates drilling fluid down the drill string **242**. The drilling fluid and entrained drill cuttings return up an annulus **252** formed by the drill string **242** and the wellbore **244**. During drilling, both pressure chambers **140, 142** of the actuator **120** communicate with the drilling fluid in the drill string **244** and thus both pressure chambers **140, 142** have approximately the same applied pressure as the drilling fluid in the drill string **242**. Accordingly, the opposing forces created by the pressures in the first and second chambers **140, 142** are substantially equal and balance each other. Thus, advantageously, the actuator **120** remains substantially stationary regardless of the applied pressure value or pressure fluctuations inside the drill string **242**.

[0047] Once the liner drilling assembly **246** drills to a desired depth, the liner hanger **248** can be actuated in the following manner. In embodiments utilizing occlusion of the bore **126**, such as in **Fig. 2A** and **2B**, drilling is halted and the occlusion member **174** is "dropped" into the drill string **242**. The occlusion member **174** flows down through the drill string **242** until it mates with the sealing member **172** to form an occlusion in the drill string **242** that hydraulically separates the first pressure chamber **140** from the second pressure chamber **142**. Thereafter, the mud pump **240** is operated to increase the applied pressure of the drilling fluid in the drill string **242**. Because of the occlusion, the applied pressure will increase only in the drilling fluid column inside the drill string **242** and uphole of the occlusion. The drilling fluid column in the drill string **242** and below the occlusion will remain at a lower applied pressure. Because the first pressure chamber **140** communicates with the fluid uphole of the occlusion, the applied pressure in first pressure chamber **140** increases relative to the pressure in the second pressure chamber **142**, which is communication with the drilling fluid downhole of the occlusion. Once a sufficient pressure differential is created between the first and second pressure chambers **140**, **142**, the net force applied by the first pressure chamber **140** urges the cylinder **130** longitudinally toward the slips **52**. Via the slip retainer **54**, the cylinder **130** drives the hanger slips **52** into engagement with the casing **238**.

**[0048]** In addition to being largely immune from pressure fluctuations during drilling, the actuator **120** also cannot be inadvertently actuated by pressure fluctuations when the liner drilling assembly **248** and drill string **244** are run into the hole (*e.g.*, due to surge).

**[0049]** It should be appreciated that embodiments of the present invention provide numerous operational and situational advantages. For example, during drilling, formations having relatively a low fracture pressure could be encountered. In such a situation, increasing the pressure in the wellbore to set a liner hanger could expose the formation to excessive applied pressures. With embodiments of the present invention, it should be seen that the increased applied pressure used for actuating the tool actuator and thereby setting the liner hanger is confined mostly within the drill string. Thus, the formation is largely protected from damage that would otherwise occur if exposed to applied pressure in excess of the formation fracture pressure.

**[0050]** In another example, during drilling, the hydrostatic pressure external to the drill string could be significantly lower than the hydrostatic pressure within the drill string. Such a situation could arise, for instance, where drilling fluid lost to the formation reduces the hydrostatic pressure of the drilling fluid flowing up the wellbore annulus. Because operation of the tool actuator is initiated by actively controlling pressure within the drill string, the tool actuator is largely immune to the value the hydrostatic pressure of fluid external to the drill string or tool actuator. That is, even a dramatic drop in external pressure will not induce movement of the actuator since the resistive force opposing movement utilizes hydrostatic pressure within the actuator to prevent unintended activation of the actuator.

**[0051]** It should further appreciated that the teachings of the present invention can be readily applied to numerous tools outside the liner drilling context. For example, in certain applications, fluids such as water, acids, fracturing fluids, may be circulated in the wellbore. Also, formation fluids such as oil and water can be utilized in some circumstances to energize the actuator.

**[0052]** Some embodiments of the present invention can be adapted for use in situations where fluid pressure is not used to energize a tool or device. For example, some tools may be actuated or energized by vibrations, mud pulse, motion of the tool, frequency, electronic signals, etc. Aspects of the present invention, including, but not limited to the use of opposing forces, can be advantageously applied in such circumstances.

**[0053]** Further, it should be understood that while the embodiments described illustrate only two pressure chambers, additional pressure chambers can be added to further extend the utility of devices made in accordance with the present invention. In the same regard, while actuation of the a wellbore tool has been described, embodiments of the present invention can be readily adapted to return a wellbore tool to a condition prior to actuation (*e.g.*, turn a tool on and off, set and set a tool, etc.)

**[0054]** Additionally, it should be understood that the terms such as "first" and "second" and "uphole" and "downhole" do not signify any specific priority, importance, or orientation but are merely used in better describe the relative relationships between the items to which they are applied. Also, the term longitudinal generally refers to a direction along the long axis of a wellbore or tool, but as noted above, the actuator is not limited to motion in any particular direction.

[0055] The foregoing description is directed to particular embodiments of the present invention for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above are possible without departing from the scope and the spirit of the invention. It is intended that the following claims be interpreted to embrace all such modifications and changes.

## THE CLAIMS

1. A method for actuating a wellbore tool, comprising:

   (a) operatively connecting an actuator to the wellbore tool;

   (b) conveying the wellbore tool and the actuator into a wellbore;

   (c) preventing activation of the actuator by using a resistive force that is generated at least partially by an applied pressure of a fluid in the wellbore; and

   (d) activating the actuator by overcoming the resistive force.

2. The method of claim 1 wherein the actuator is activated by increasing a applied pressure applied to the actuator.

3. The method of claim 1 wherein the actuator includes a first pressure chamber adapted to generate a motive force for activating the actuator.

4. The method of claim 3 wherein the actuator includes a second pressure chamber adapted to generate the resistive force for resisting activation of the actuator.

5. The method of claim 4 further comprising applying a different applied pressure to each of the first and second pressure chambers to activate the actuator.

6. The method of claim 4 further comprising using a work string to convey the wellbore tool and the actuator into the wellbore; pumping the fluid into the drill string; selectively occluding a bore in which the fluid is flowing so that a different

applied pressure can be applied to each of the first and second pressure chambers.

7. An apparatus for actuating a tool adapted for use in a wellbore, comprising:

(a) an actuator operatively coupled to the wellbore tool;

(b) a first pressure chamber adapted to generate a motive force that displaces the actuator;

(c) a second pressure chamber adapted to generate a resistive force that resists motion of the actuator; and

(d) a pressure control device that selectively applies pressure to the first and second pressure chambers.

8. The apparatus of claim 7 wherein the actuator includes an actuating member.

9. The apparatus of claim 7 wherein the actuator includes a cylinder slidably disposed on a mandrel, the first and second pressure chambers being formed therebetween.

10. The apparatus of claim 9 further comprising a first and second port formed in the mandrel that provide fluid communication between a fluid body and the first and second pressure chambers, respectively.

11. The apparatus of claim 10 wherein the pressure control device is adapted to substantially hydraulically isolate the first pressure chamber from the second pressure chamber.

12. The apparatus of claim 10 wherein the pressure control device includes a sealing member positioned between the first and second ports, the sealing member being adapted to receive an occlusion member that forms a hydraulic seal upon being seated thereon.

13. The apparatus of claim 7 wherein the first pressure chamber generates a motive force that displaces the actuator upon receiving fluid at a predetermined applied pressure.

14. The apparatus of claim 7 wherein the tool is a liner hanger.

15. A system for operating a tool for use in a wellbore, comprising:

(a) a rig at a surface location;

(b) a work string adapted to convey the tool into the wellbore from the rig;

(c) an actuator coupled to the tool, the actuator including a first and second pressure chamber in communication with a fluid in the work string, the first and second chambers adapted to generate forces in substantially opposing directions; and

(d) a pressure control device adapted to selectively substantially hydraulically isolate the first and second pressure chambers from each other.

16. The system according to claim 15 further comprising a pump at the surface location adapted to selectively increase an applied pressure of the fluid in the work string.

17. The system according to claim 15 further comprising a liner drilling assembly coupled to the work string; and wherein the tool is a liner hanger associated with the liner drilling assembly.

18. The system according to claim 17 wherein the actuator includes a cylinder slidably mounted on a mandrel, the first and second pressure chambers being formed therebetween.

19. The system according to claim 18 wherein the liner hanger includes slips adapted to extend radially upon a sliding motion of the cylinder.

20. The system according to claim 15 wherein the pressure control device includes a sealing member adapted to receive an occlusion member, the mating of the occlusion member and the sealing member substantially hydraulically sealing the first pressure chamber from the second pressure chamber.

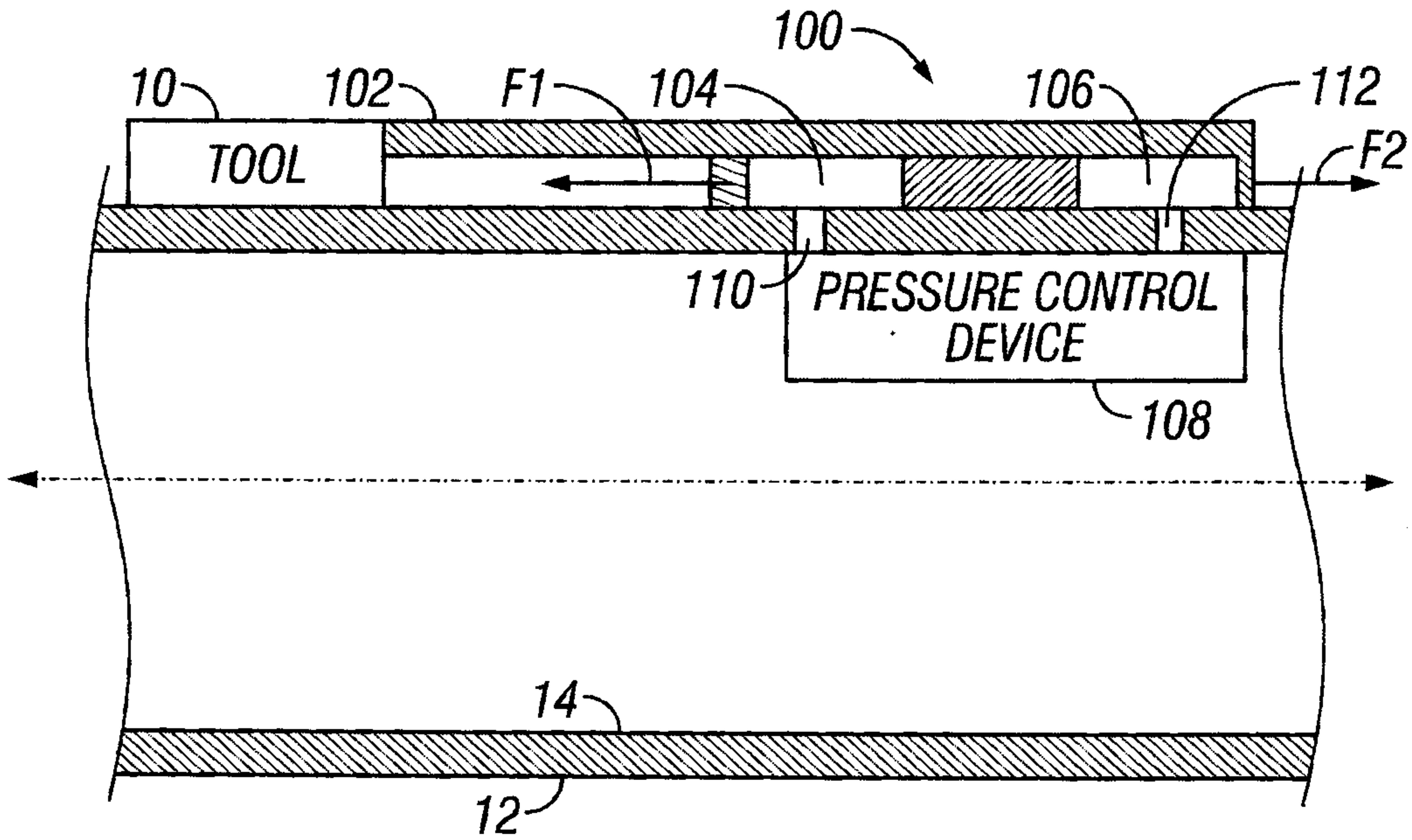

100
10
102
F1
104
106
112
TOOL
F2
110
PRESSURE CONTROL DEVICE
108
14
12

FIG. 1

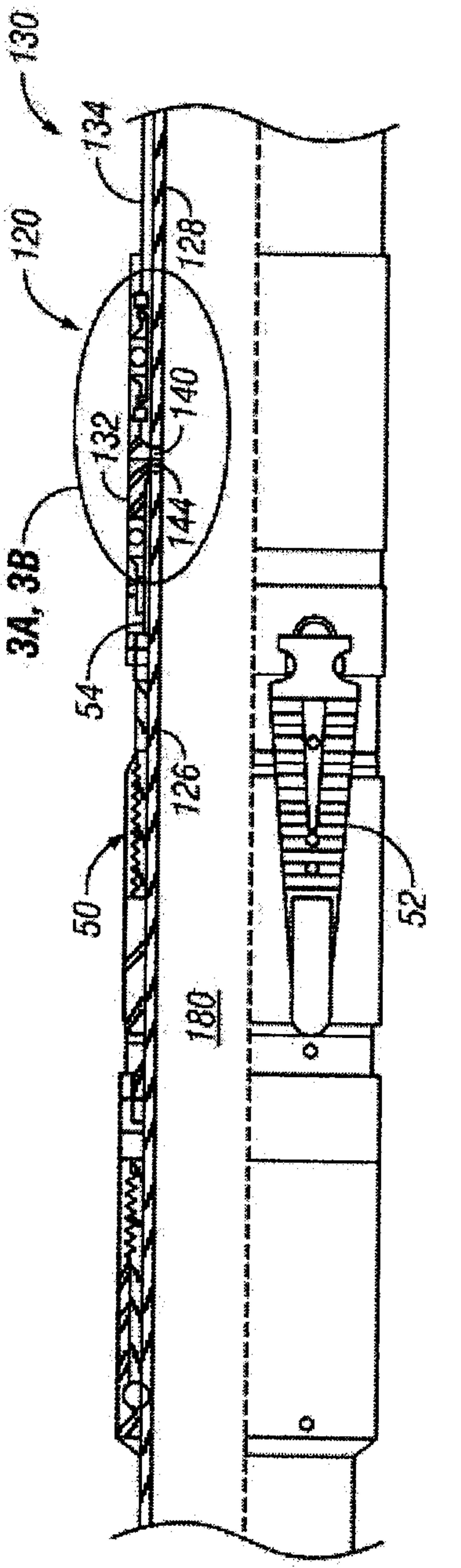
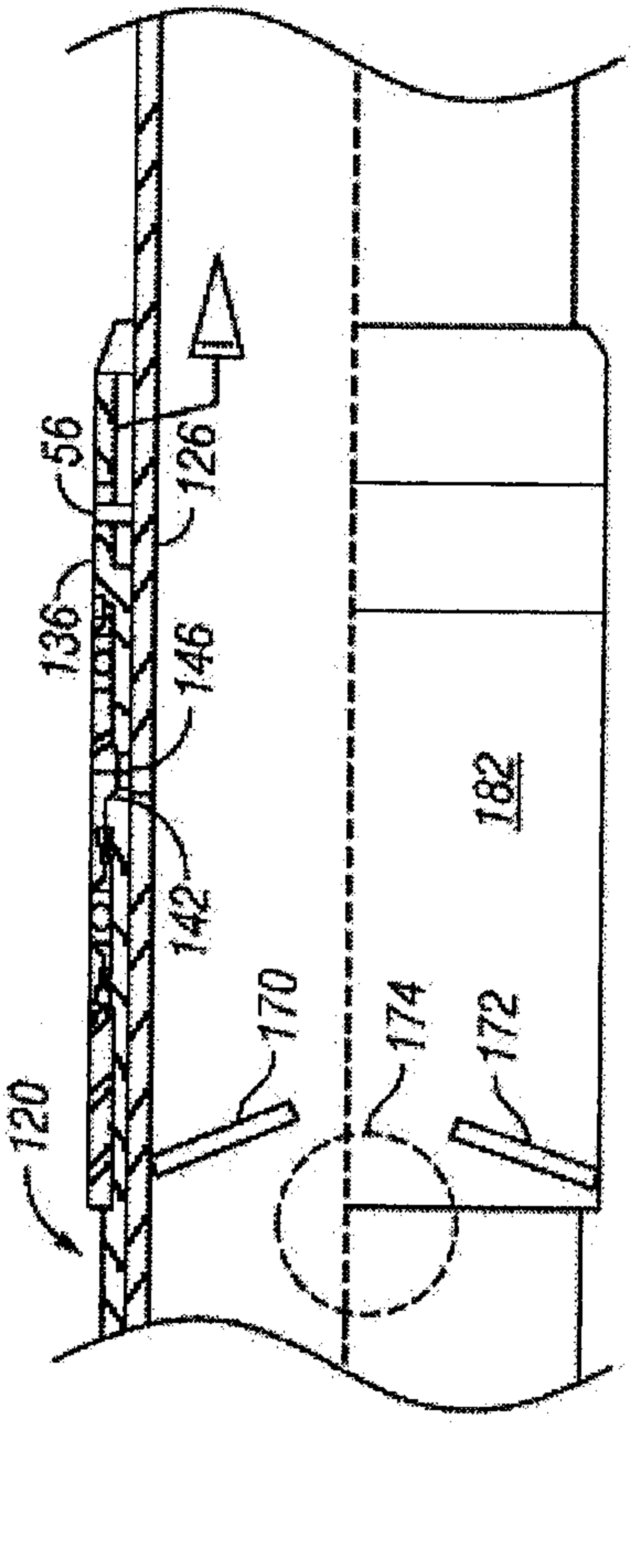

130
134
120
128
140
132
144
3A, 3B
54
126
50
180
52

FIG. 2A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126
136
146
142
182
170
174
172
120

FIG. 2B

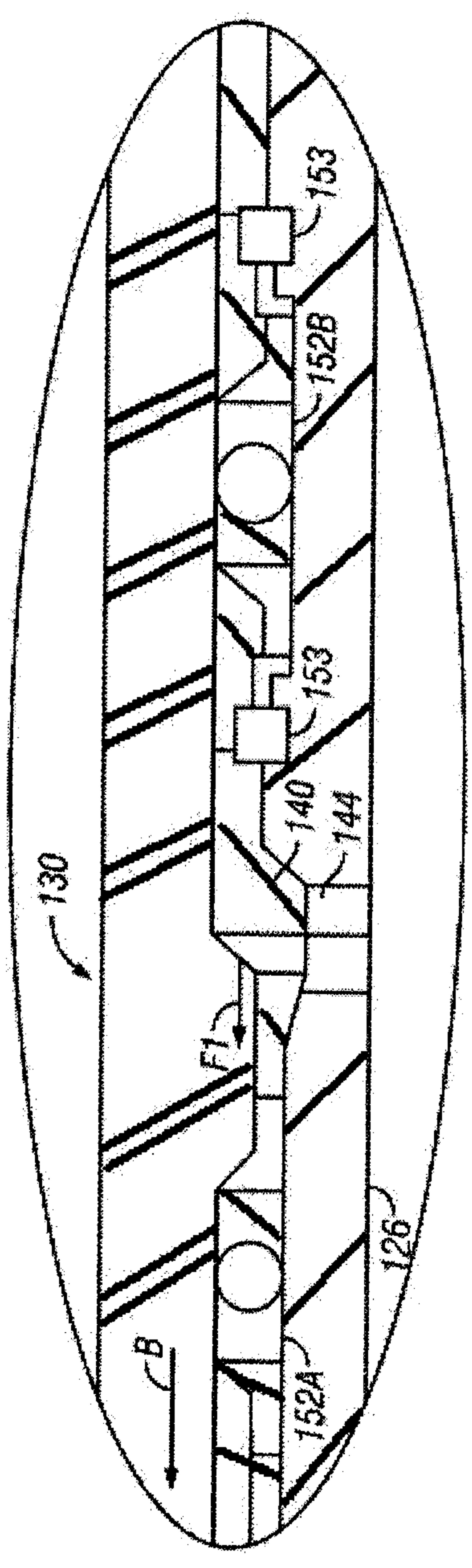

130
153
152B
153
140
144
F1
B
126
152A

FIG. 3A

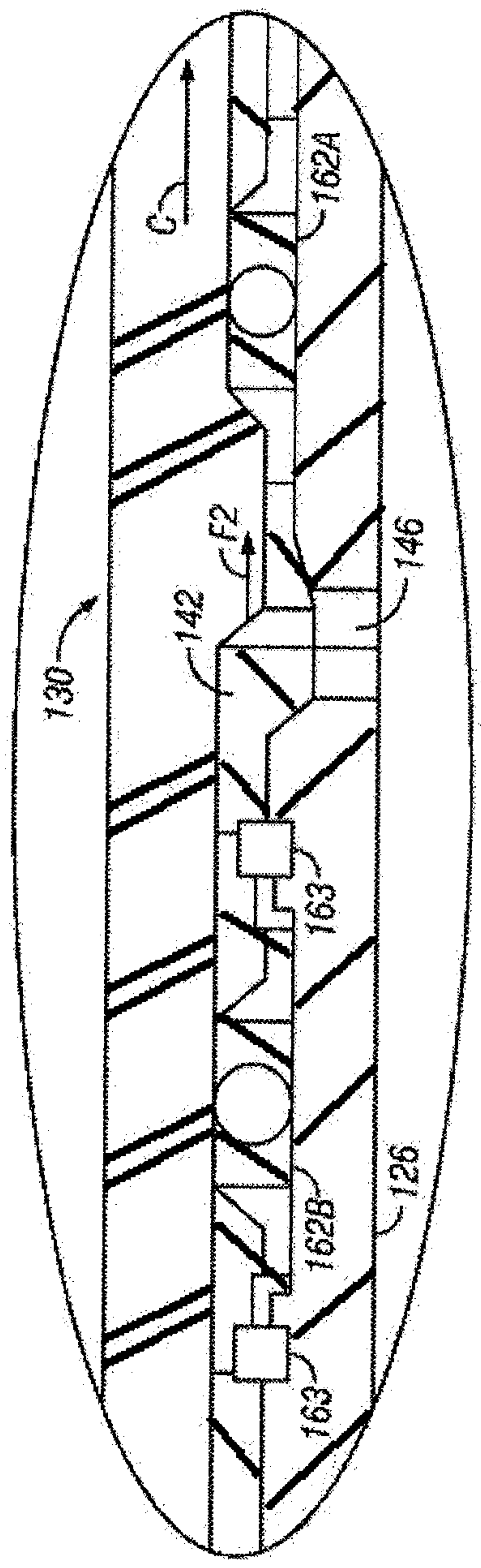

C
162A
F2
142
146
130
163
162B
126
163

FIG. 3B

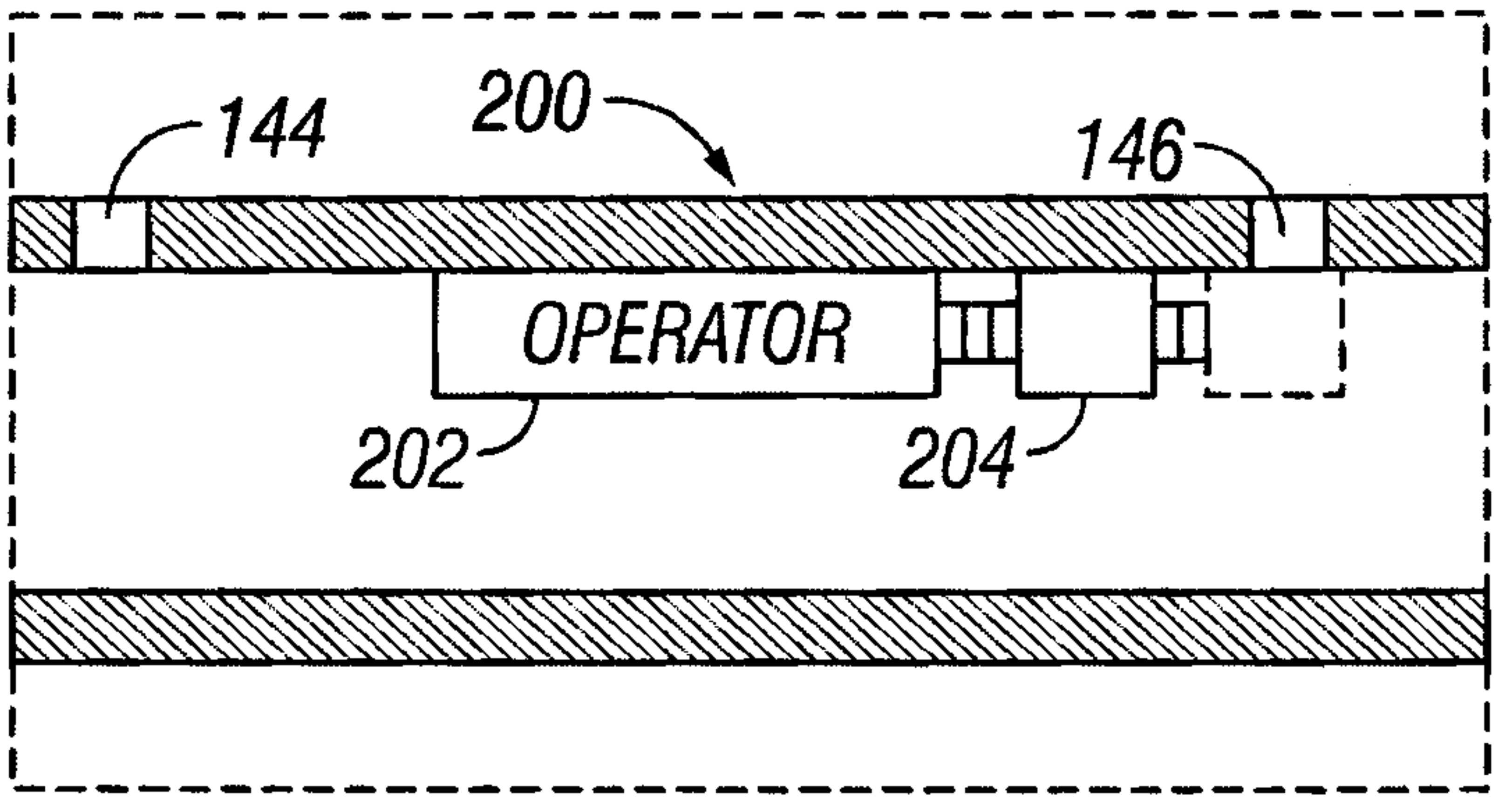



FIG. 4

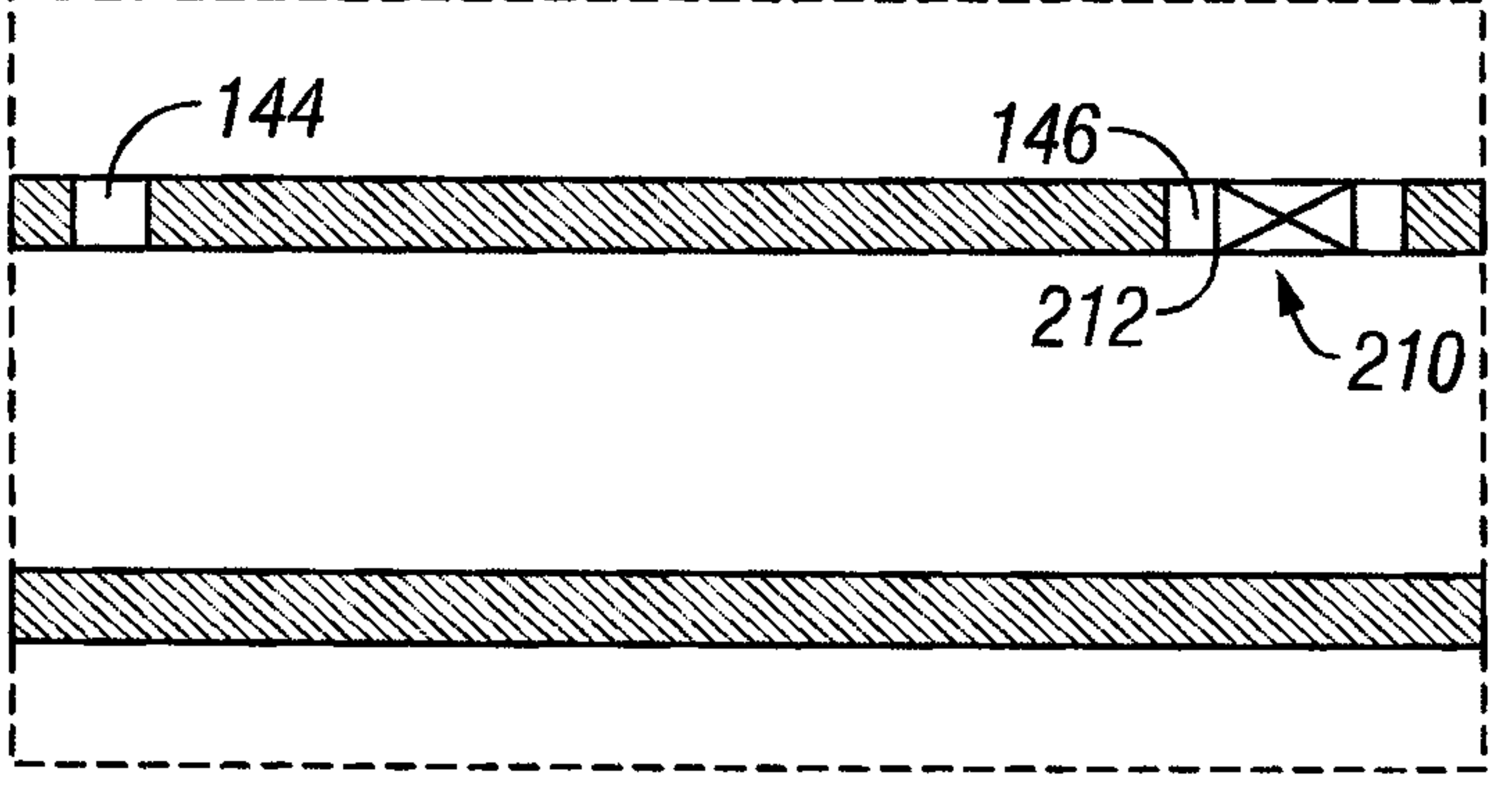



FIG. 5

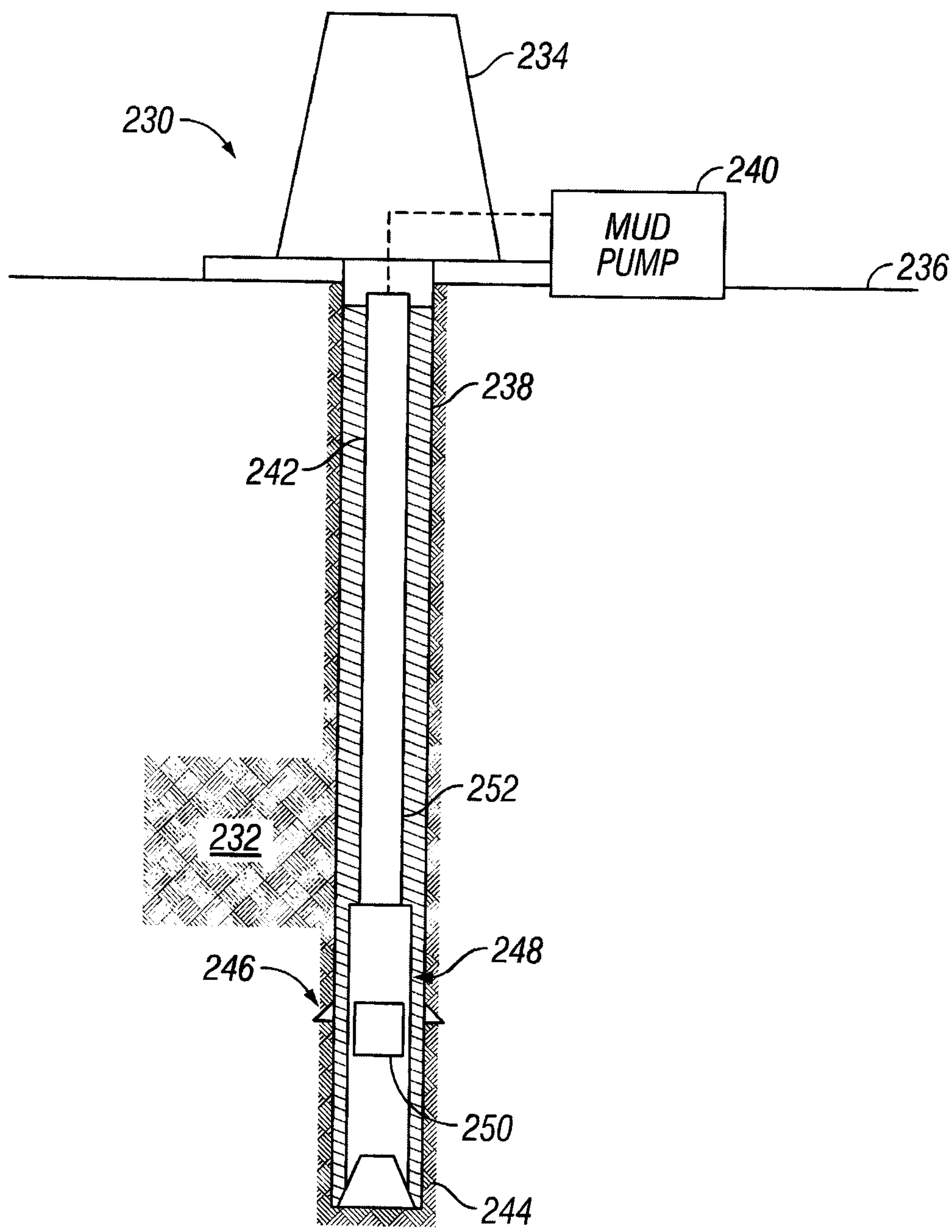
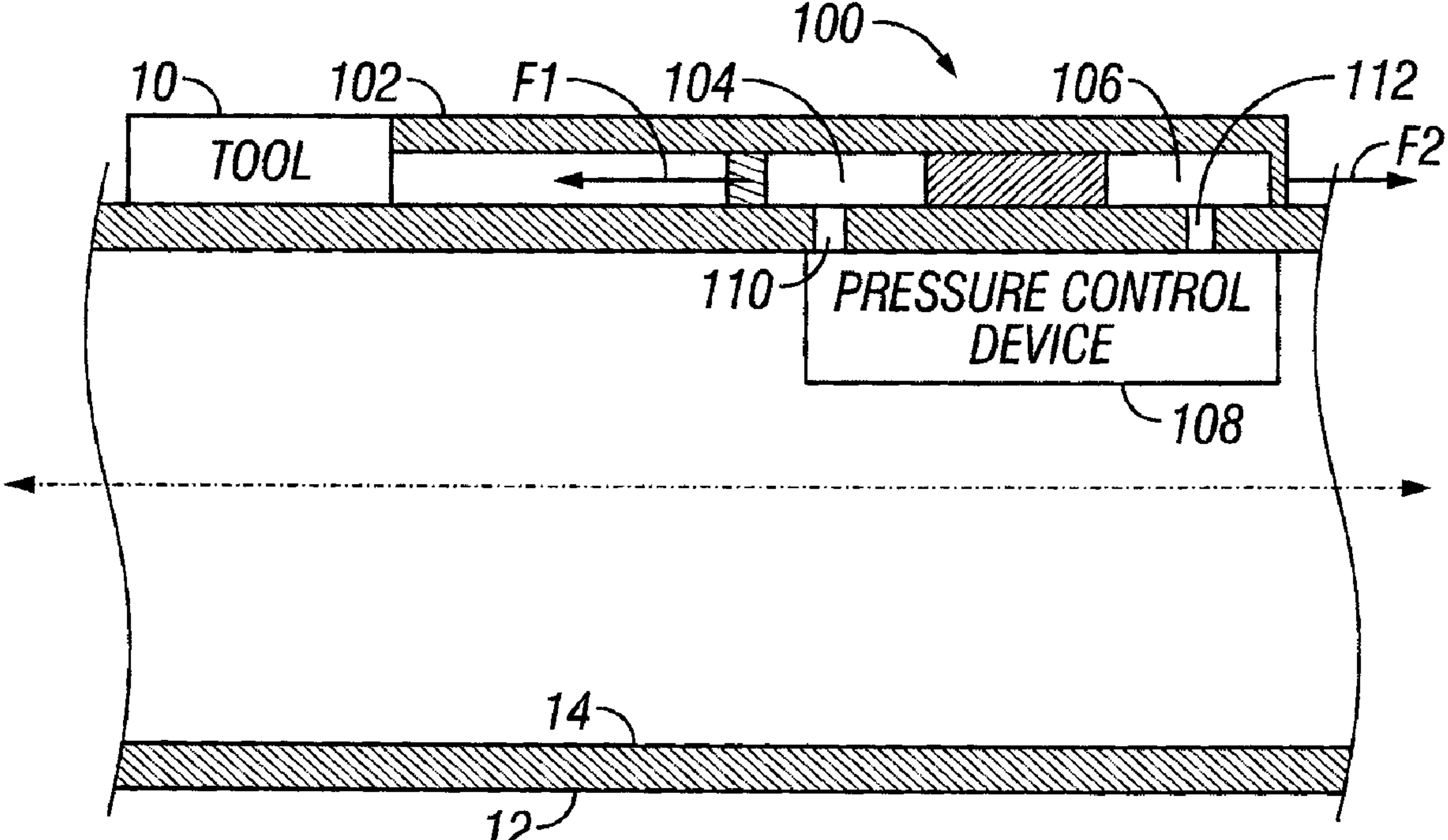



FIG. 6


100
10
102
F1
104
106
112
TOOL
F2
110
PRESSURE CONTROL DEVICE
108
14
12